Radiometric Performance Assessment of Suomi NPP VIIRS SWIR Band (2.25 µm)

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Abstract

Suomi NPP VIIRS SWIR band M11 (2.25 µm) has larger radiometric uncertainty compared to the rest of the reflective solar bands. This is due to a number of reasons including prelaunch calibration uncertainties. One of the most commonly used technique to verify the radiometric stability and accuracy of VIIRS is by intercomparing it with other well calibrated radiometers such as MODIS. However one of the limitations of using MODIS is that VIIRS band M11 RSR doesn't overlap with MODIS bands at all. Thus the accuracy of intercomparison relies completely on how well the spectral differences are analyzed over the given target. This study uses desert sites to analyze M11 radiometric performance. In order to better match the RSR between instruments, we have chosen Landsat 8 OLI SWIR band 2 (2.20 µm) to perform intercomparison. This is mainly because OLI SWIR band 2 fully covers the VIIRS band M11 even though OLI has much wider RSR compared to VIIRS. The impact due to spectral differences is estimated and accounted for using EO-1 Hyperion observations and MODTRAN.

Introduction

- The radiometric stability and accuracy of VIIRS is critical to make its data useful for weather and climate applications.
- VIIRS on-orbit radiometric performance is regularly monitored and analyzed using well established calibration sites (such as Libya-4, Sudan-1, Dome C calibration sites) and through the inter-comparison with other satellite instruments such as AQUA MODIS and Landsat 8 OLI.
- This study uses a well characterized Libya-4 Saharan desert calibration site to monitor the radiometric performance of VIIRS SWIR band M11 (2.25 µm).
- It is more complicated and challenging to accurately calibrate VIIRS M11 band at lower radiance because the reflected radiance for M11 is very small on the order of 0.1 - 0.2 w/m^{2}sr^{-1} or less over ocean compared to nearly 7-8 w/m^{2}sr^{-1} over desert.
- We have focused on Libya-4 calibration site under the assumption that the detectors are linear and results obtained at higher radiance is also valid at lower radiance.
- It is assumed that both AQUA MODIS and Landsat-8 OLI are correct in absolute scale and the sensor intercomparison is performed with MODIS and OLI to assess how well the band M11 is calibrated.
- M11 doesn't overlap with any AQUA MODIS bands. Still the comparison study is performed with closest matching MODIS band assuming that the spectral differences could be characterized using hyperspectral measurements.

Methodology

Sensor	S-NPP VIIRS	Landsat-8 OLI	AQUA MODIS	EO-1 Hyperion
Spatial Resolution	750 m	30 m L1GST	1 km	30 m

Libya-4 Desert calibration site

- Libya-4 (28.55°, 23.39°) is a CEOS endorsed cal/val site.
- It is a Saharan desert calibration site used mostly for on-orbit cal/val of VNIR radiometers.

Figure 1. Calibration Site

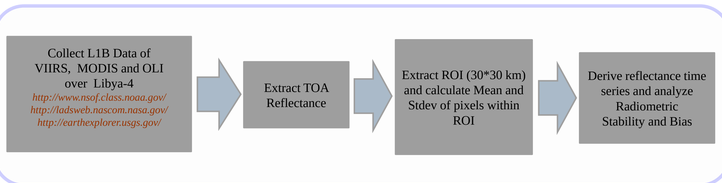

Figure 2. Estimate VIIRS bias over Libya-4

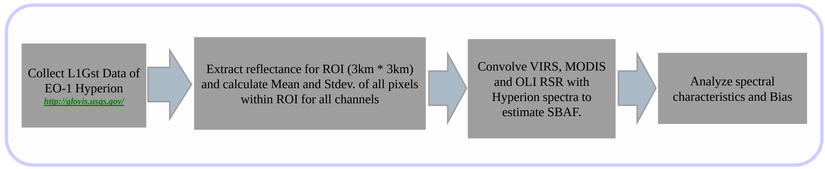

Figure 3. Estimate VIIRS spectral bias over Libya-4 using EO-1 Hyperion

Results

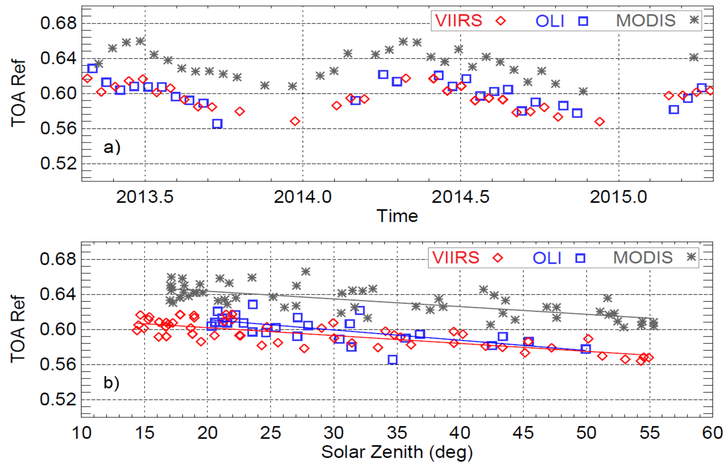

Figure 4. VIIRS, MODIS and OLI TOA reflectance over Libya-4 as a function of a) Time b) Solar Zenith Angle

- VIIRS M11 band and its matching MODIS and OLI bands suggest noisier time series.
- OLI and MODIS RSRs are near the water vapor absorption wavelength and are impacted by atmospheric water vapor absorption variability.
- Bias is analyzed as a function of solar zenith angle to reduce the impact due to bidirectional reflectance distribution function (BRDF).
- VIIRS observed bias (before accounting impact due to spectral differences) is 1.44% relative to OLI and 6.5% relative to MODIS with 1-sigma uncertainty on the order of 1.4%.
- Short term anomalies are not clearly noticeable due to higher variability in the time series. Change in data trend due to major calibration updates and anomalies further increases the uncertainty.

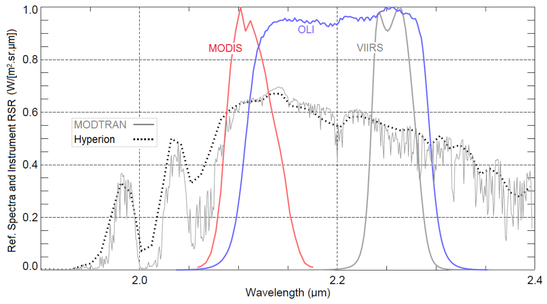

Figure 5. VIIRS, MODIS and OLI matching bands. MODIS and M11 RSR doesn't overlap at all. OLI completely covers M11 RSR but has much wider bandwidth.

- MODTRAN reflectance is scaled to match the maximum value with Hyperion near 2.2 µm.
- Reflectance spectra from Hyperion and MODTRAN match well with each other except over the region where atmospheric absorption is large.
- The reason is mainly because the atmospheric water vapor contents are different for Hyperion and MODTRAN.
- Spectral bias computed using Hyperion is 6.7% relative to MODIS and 6.9% relative to OLI.
- The uncertainty is much larger for MODIS (3.1%) compared to OLI (0.9%).

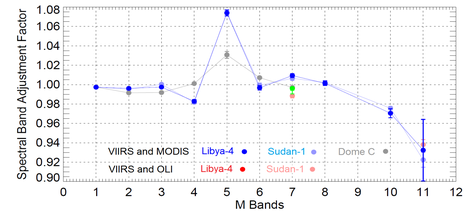

Figure 6. SBAF of VIIRS bands computed using MODIS and OLI (*Ref: Uprety et al. 2015*). Large number of Hyperion observations (150 over Libya-4) used to estimate the SBAF.

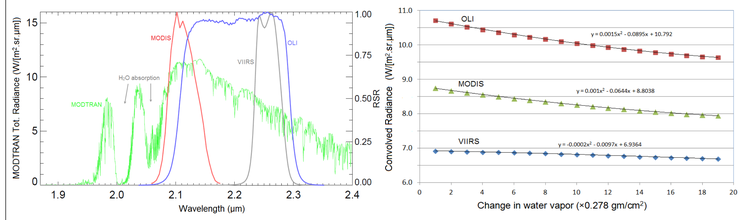

Figure 7. Left: Radiance spectra over desert using MODTRAN. MODIS and OLI are more susceptible to water vapor absorption Right: Radiance trend generated by changing water vapor from 0.278 to 5.28 gm/cm^2

- With change in water vapor input, the maximum change in radiance is 3.1% for VIIRS, 9% for OLI and 10% for MODIS indicating MODIS and OLI bands being largely impacted by atmospheric water vapor compared to VIIRS.

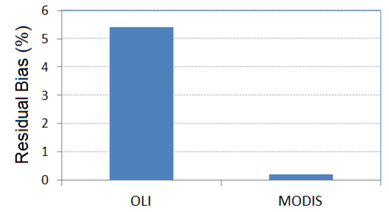

Figure 8. VIIRS M11 bias over Libya-4 desert estimated using TOA reflectance trending, Bias=(V-M)×100%/M (after accounting RSR differences between the matching VIIRS and MODIS bands).

- The residual bias of VIIRS is the difference between observed bias and spectral bias.
- Even though VIIRS and OLI measurements agree very well to less than 1.5%, the spectral differences suggest large true bias.
- The residual bias of VIIRS is nearly 6% relative to OLI and nearly 0.5% relative to MODIS.

Summary

- The radiometric stability of VIIRS moderate resolution reflective solar band M11 analyzed using Libya-4 desert site is better than 1% with uncertainty less than 1%.
- VIIRS M11 radiometric bias (analyzed after accounting for spectral differences) estimated through VIIRS band M11 inter-comparison using TOA reflectance time series over desert suggest nearly 5.4% relative to OLI and less than 0.5% relative to MODIS.
- The result from this study is valid for low radiance under the assumption that detector responses are linear over the dynamic range (Lmin: 0.12 to Lmax: 31.8 W m^{-2} sr^{-1}µm^{-1}) of M11.
- The root cause for large VIIRS bias relative to OLI needs to be investigated in the future.
- The discrepancy in bias relative to OLI and MODIS also needs to be further investigated in more detail.

References:

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[3] Uprety, S., & Cao, C. Suomi NPP VIIRS reflective solar band on-orbit radiometric stability and accuracy assessment using desert and Antarctica Dome C, Remote Sensing of Environment http://dx.doi.org/10.1016/j.rse.2015.05.021

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Acknowledgment :

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